Lessons Learned from the World's Largest Digester Gas Fuel Cell

Washington State Recycling Association - Spokane
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Presentation Outline

- County Recycling Efforts
- Introduction to fuel cells
- King County 1 MW fuel cell project overview
- Emissions and performance data
- Lessons learned
- Conclusions

WTD Vision

CREATING RESOURCES FROM WASTEWATER

- Biosolids Recycling
- Biogas Management
- Grit Recycling
- Reclaimed Water Production/Distribution

Biosolids Recycling

- King Co. has recycled 100% of it's biosolids for nearly four decades
- Biosolids is used for forest fertilization, soil improvement in agriculture and compost production
- Bio-diesel will be produced

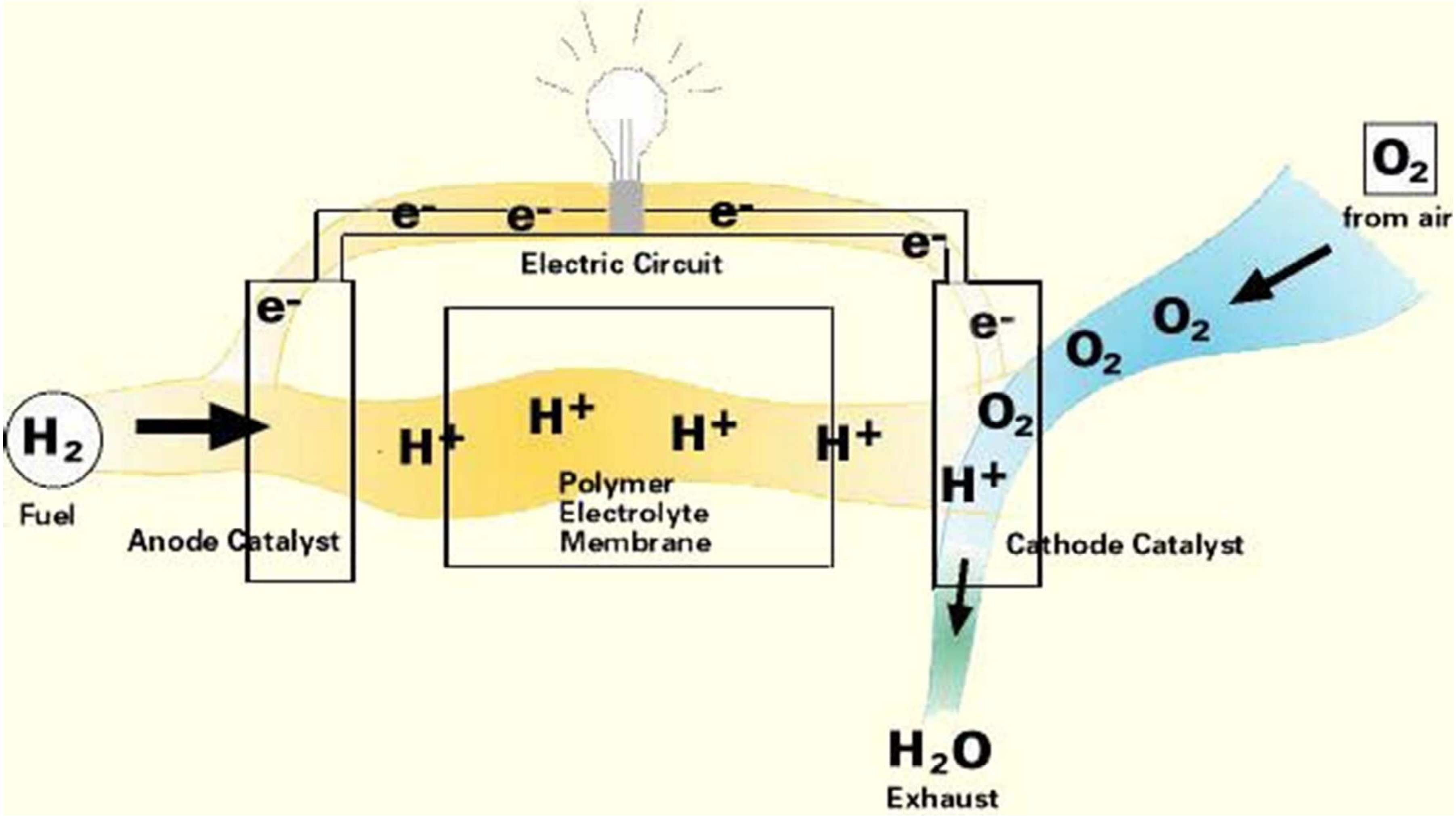
Biogas Management

- South Plant 1 MW fuel cell and 8 MW cogen facility
- West Point 4.6 MW engine/generators
- BrightWater will allocate space for future cogen and build energy education center

Reclaimed Water

- Currently produce 3 MGD
- Customers near South Plant
- BrightWater “Backbone” project will use MBR technology to produce 5 to 7 MGD for distribution in several areas by 2011
- Regional water supply planning underway

How Fuel Cells Work



(Source: www.fuelcells.org)

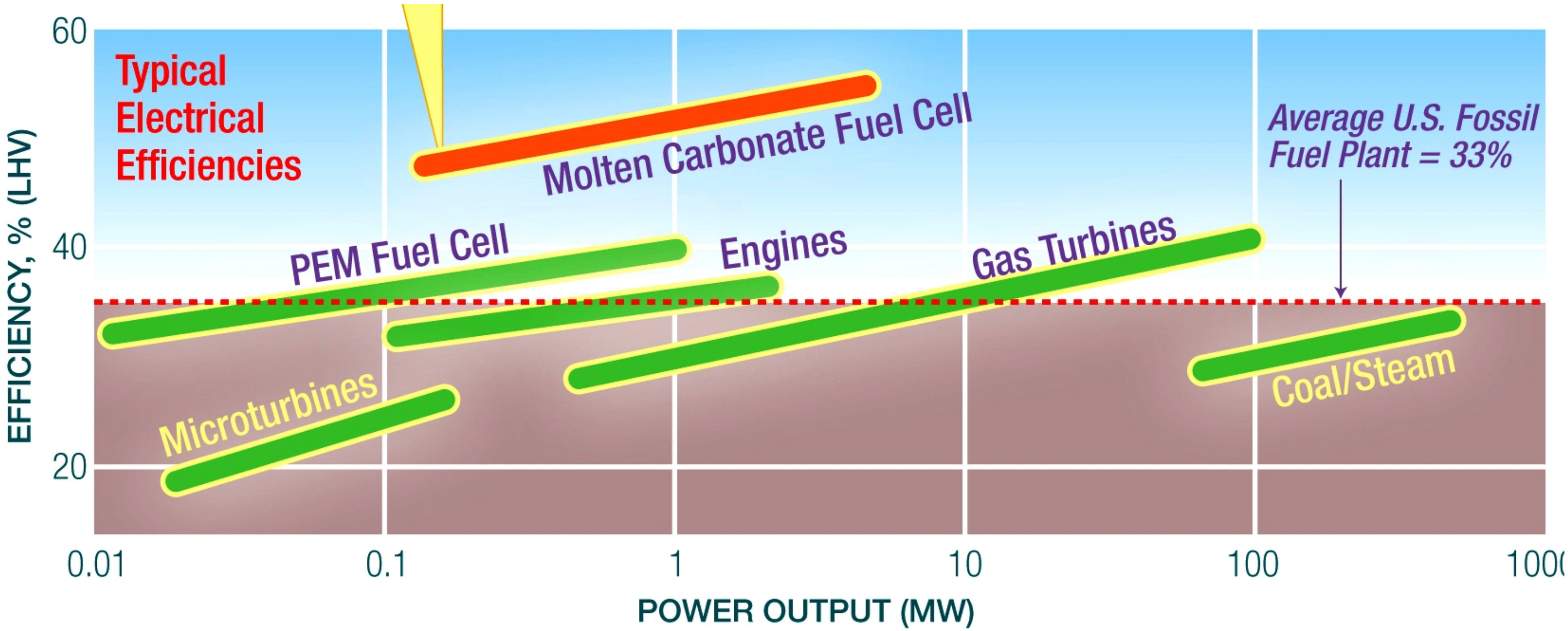
Fuel Cell Types

TYPE	ELECTROLYTE	OPERATING TEMP. °F	SINGLE-CYCLE ELECTRICAL EFFICIENCY %	EXPECTED CAPACITY RANGE	BY-PRODUCT HEAT USE
PEM	Polymer Membrane	180	30-35	5 kW to 250 kW	Warm Water
Alkaline	Potassium Hydroxide	200	<40	3 to 5 kW	Warm Water
Phosphoric Acid	Phosphoric Acid	400	35-40	50 kW to 200 kW	Hot Water
Molten Carbonate	Potassium/ Lithium Carbonate	1200	45-57	250 kW to 2 MW	High Pressure Steam
Solid Oxide (Tubular)	Stabilized Zirconium Dioxide Ceramic	1800	45-50	100 kW to 2 MW	High Pressure Steam
Solid Oxide (Planar)	Stabilized Zirconium Dioxide Ceramic	1200-1600	45-60	3 kW to 10 kW	High Pressure Steam

Fuel Cells Today

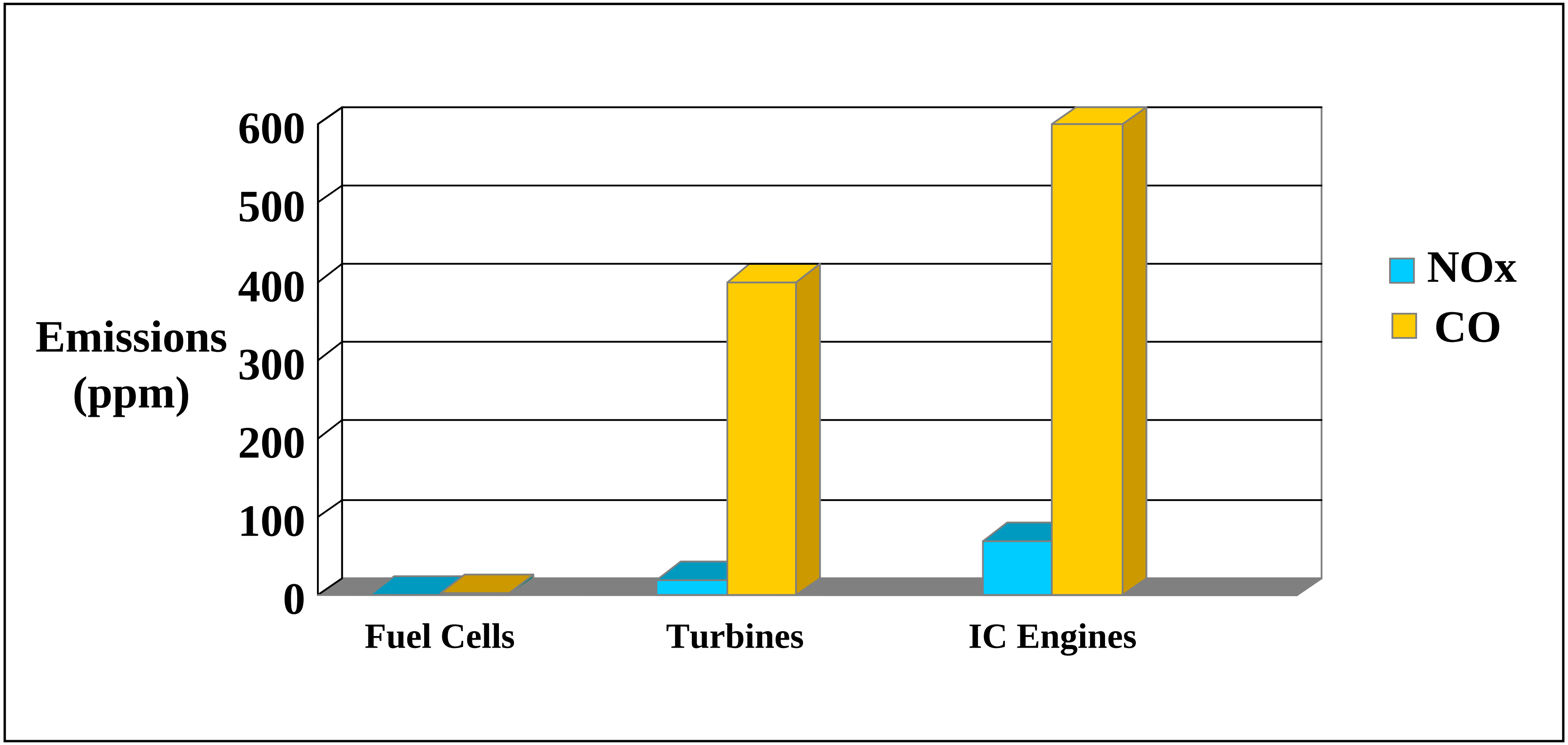
- Established technology
  - defined product lines and end markets
  - over 2,000 fuel cells in over 26 countries (http://www.fuelcells.org)
- Economically viable (with incentives)
- Near zero emissions
- Ability to leverage existing gas infrastructure
- High quality and reliable power
- Ability to site near where power is used
  - removes transmission and distribution losses
  - grid congestion increasing

Comparison of Efficiencies



Note: Efficiencies do not include gas pretreatment or heat recovery

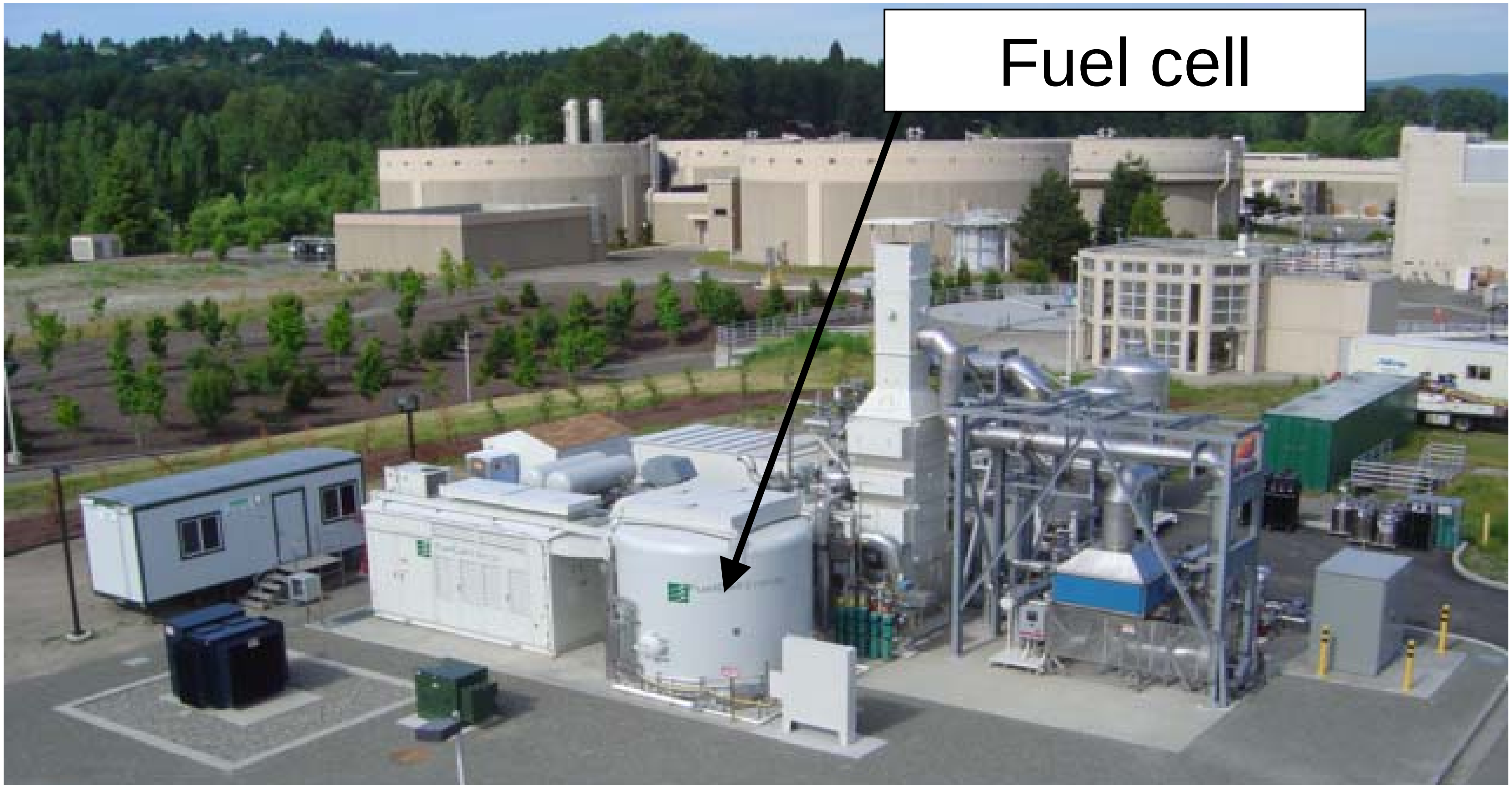
Fuel Cell Benefit - Low Emissions



Fuel Cell Users

Facilities that want reliable power and have an available gas source

King County 1 MW Fuel Cell Demonstration Project



Site Location

- South Treatment Plant - Renton, WA
- 80 acre facility treats 70 mgd
  - average wet weather capacity = 115 mgd
- One of two King County regional wastewater plants
  - third plant in design
- Approximately 1/2 acre site for fuel cell
- Conventional mesophilic anaerobic digestion

Project Goals

- Demonstrate that molten carbonate fuel cell technology can be adapted to use anaerobic digester gas
- Show that 1 MW (net A.C.) can be produced using either digester gas or natural gas
- Continue King County leadership in technology development and sustainability
- Show evidence of the potential for on-site generation with low air emissions

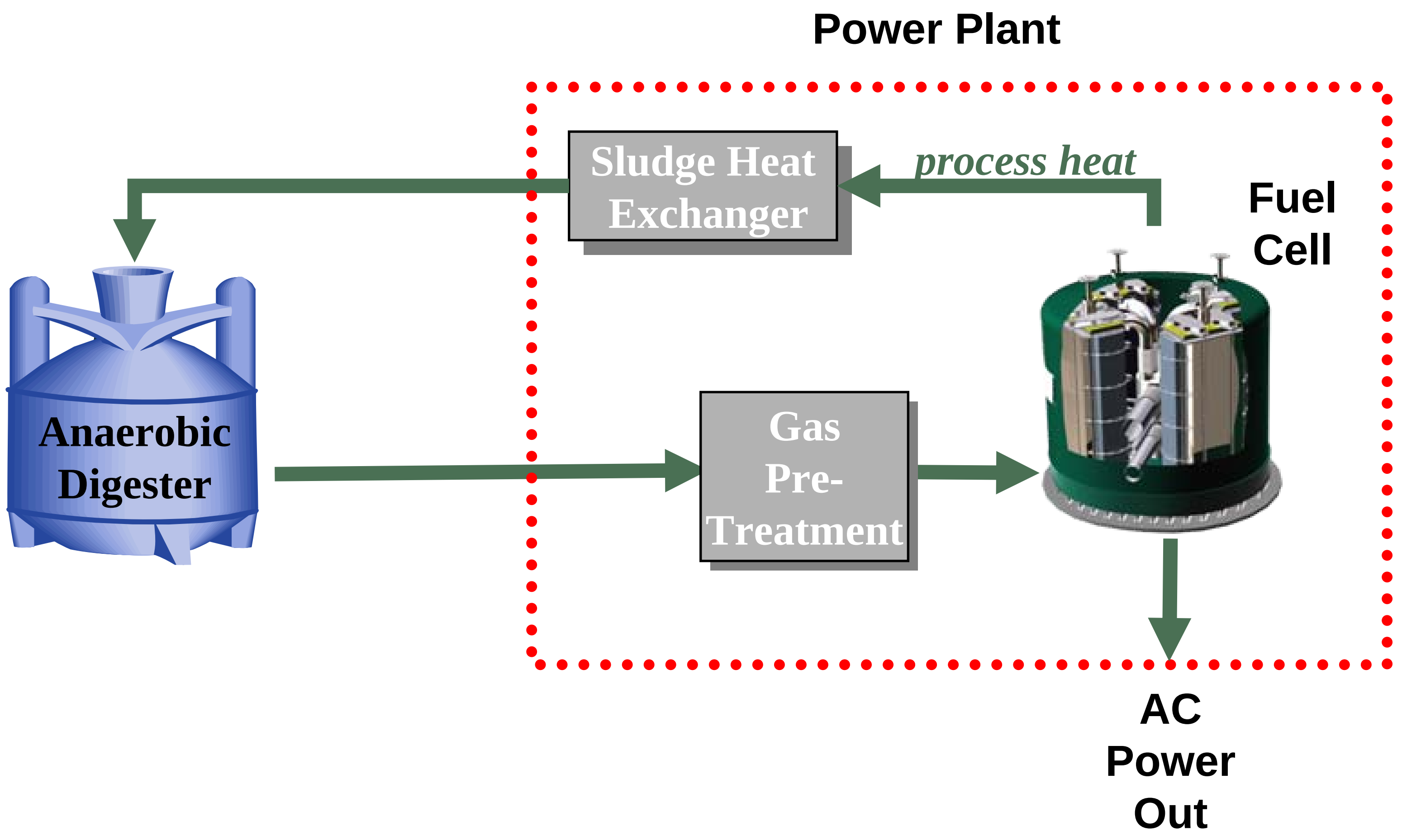
Operations Objectives

- Highly automated daily operation
- Remote monitoring with local alarms
- Operation and maintenance handled by plant staff
- Waste heat used within plant

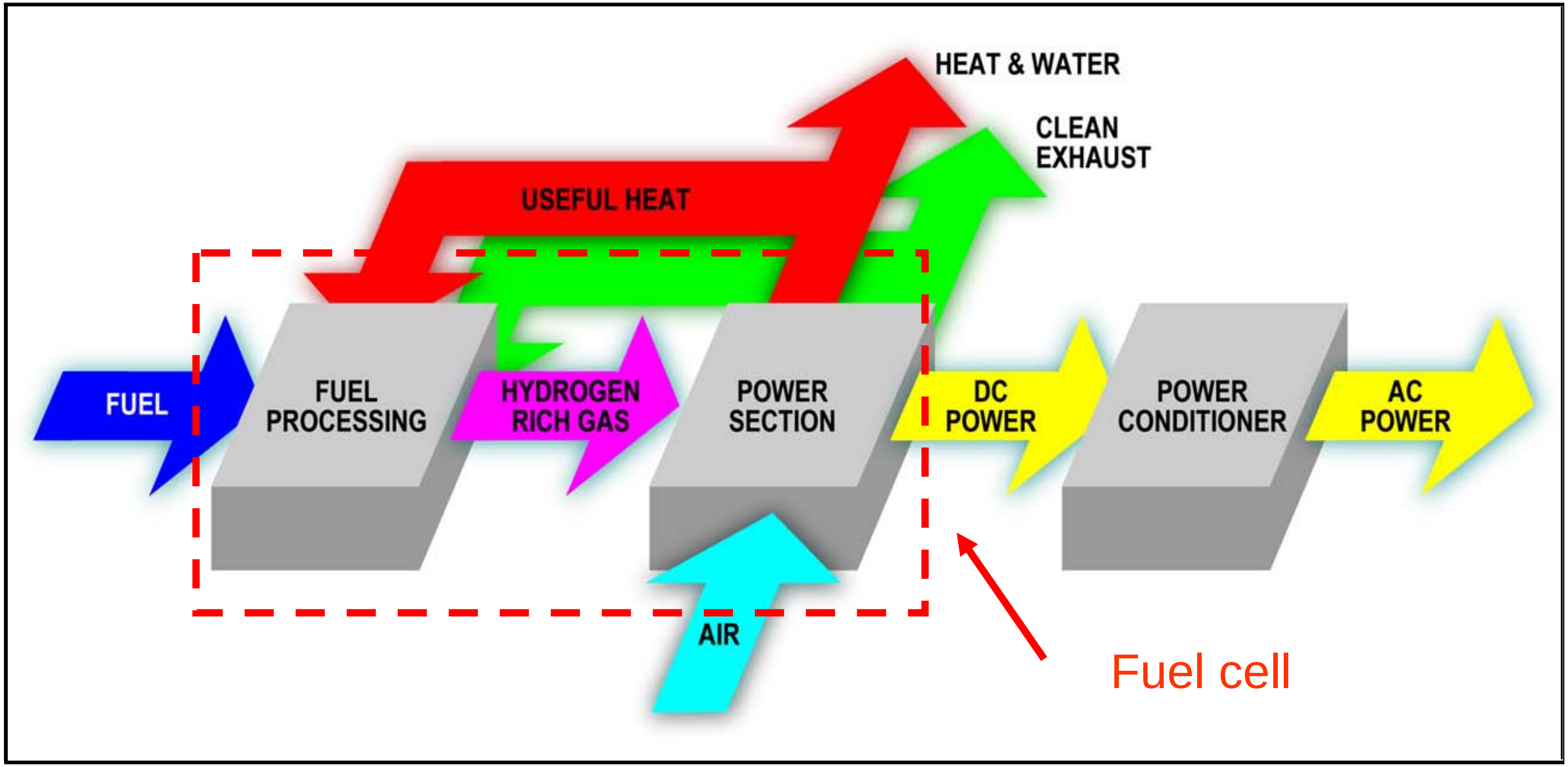
Project Schedule

- Construction - April 2003 to April 2004
- Start-up - April 2004 to June 2004
- Two-year demonstration period - June 2004 to June 2006
- Emission tests in 2004 and 2005

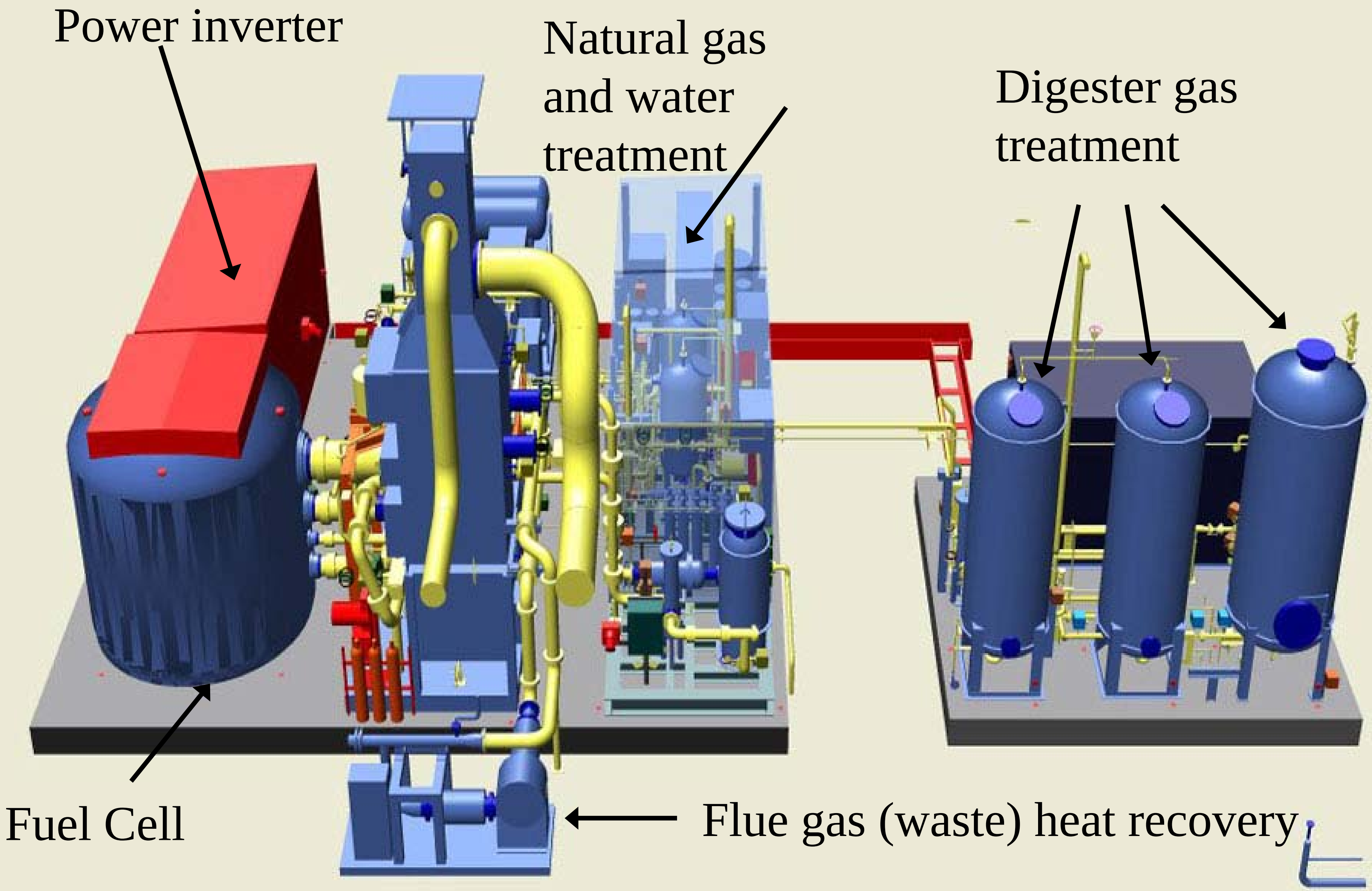
Overall Process Flow



Fuel Cell Power Plant Process Flow Diagram



Overall Plant Layout



South Plant Biogas Production

- Approximately 4 MW gas total
- Until this project, all biogas scrubbed and sold as “pipeline quality natural gas” to local gas utility
- Fuel cell uses 1 MW of gas
- Cogen will use 8 MW natural gas (approx. 3 MW from plant and 5 MW purchased from utility)

Types of Gases Used by the King County Fuel Cell

Runs on natural gas or digester gas

- Unscrubbed digester gas from plant
  - sulfur removed (SulftaTreat + carbon)
- Natural gas from the plant
  - scrubbed digester gas
  - sulfur and CO_2 removed (wet scrubber)
  - “pipeline quality”
- Natural gas from utility

Digester Gas vs. Natural Gas

Digester Gas

- Methane ~ 65%
- CO_2 ~ 38%
- LHV ~ 548 BTU/scfm
- Gas Flow to fuel cell ~ 215 scfm

Natural Gas

- Methane ~ 98%
- CO_2 ~ 0%
- LHV ~ 900 BTU/scfm
- Gas Flow to fuel cell ~ 125 scfm

Performance Goals and Actual Data

Goals

- Efficiency = 49% (lower heating value)
- Efficiency with heat recovery = 72%
- Net Power Out = 1 MW
- Availability > 80%
- Emissions
  - CO < 10 ppm
  - NOx < 2 ppm
  - NMHC < 1 ppm

Actual

- Efficiency = 43 to 47% (lower heating value)
- Efficiency with heat recovery = 60 to 65%
- Net Power Out = 1 MW (derate 2% every 6 months)
- Availability > 90%
- Emissions
  - CO $\leq$ 13 ppm
  - NOx $\leq$ 0.2 ppm
  - NMHC = non detect

Emission Testing

- Tested for:
  - Halides
  - Siloxanes
  - HAPs and TAPs
  - CO
  - NOx
  - Methane
  - Non-Methane Hydrocarbons (NMHC)

Cost of the Project

- Appropriated Federal Funding (EPA and Congress) = $9.5 million
- King County = $3.0 million
- FuelCell Energy = $11.4 million

Total = $23.9 million

Current and Future Cost of Stationary Fuel Cells

- Current
  - $5M to $8M/MW installed
  - $0.045 to $0.065/kWh
  - 40% to 50% efficient
- Future Goal
  - $1.5M/MW
  - $0.015/kWh
  - >50% efficient

Source: DOE Oak Ridge Nat'l Lab, Federal CHP Market and Fuel Cells

Lessons Learned - Construction

- Interconnect agreement with local utility difficult due to uniqueness of application
- Electrical inspection by utility challenging; third party inspector hired
- Field design required for some missing components
- Some equipment damaged during delivery
- Various skids were not “plug and play” as intended

Lessons Learned - Operations

- Integration with the plant gas system a challenge
- Constant gas quality and quantity required design modifications and new gas source
- Operation easy and high equipment availability
- Numerous components to maintain and some are expensive to replace (new stack every 3 to 5 years)
- System needs to be optimized to achieve design efficiency
- Fuel cell stack runs smoothly
- Transition from FuelCell Energy to King County operations took more time than anticipated

Conclusions

- Fuel cell technology is a viable, clean, sustainable power generation alternative
- Capital cost is competitive with other technologies if incentives are available
- Gas quality and quantity are key parameters for consistent power generation capability
- Efficiency of fuel cell technology continues to improve
- Actual installation and start-up experience learned on this project is valuable for others

Questions?

Thank you for attending this presentation!

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